CHAPTER 4. MERV ISSUES AND METHODOLOGIES FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY PROJECTS

In this chapter, we briefly review the different types of energy efficiency and renewable energy projects that will be subject to MERV guidelines and discuss one of the key MERV issues (monitoring domain) that the guidelines need to address. The rest of this chapter describes the issues connected with the use of alternative methodologies that can be used for data collection, monitoring, and evaluation.

4.1. Project Types

MERV issues for two types of projects are examined in this chapter: energy efficiency and renewable energy projects. Both types of projects may affect the generation of energy from fossil fuel sources, thus reducing GHG emissions. MERV issues for GHG emissions reductions are similar for both types of projects.

The types of energy-efficiency projects considered in this section are:

- end-use energy efficiency
- improvements in generation (e.g., capacity factor improvements, fuel switching, increases in lower emitting capacity, efficiency improvements)
- improvements in transmission and distribution (i.e., reducing losses in the delivery of electricity or district heat from the power plant to the end user)
- cogeneration and waste heat recovery
- transportation (e.g., efficient vehicles and demand reduction)

We provide a more detailed listing of end-use energy-efficiency projects in Table 7; this table is not an exhaustive list, but is for illustrative purposes only. In many cases, the proposed projects could be targeted to one or more of the building sectors (residential or commercial) as well as the industrial sector. In all cases, energy-efficiency projects reduce the amount of energy needed to provide given levels of services. If this energy is derived from carbon-based fuel combustion, GHG emissions are reduced. In this chapter, we do not cover alternative fuel vehicles, cogeneration, and methane emissions reduction projects, although methodologies similar to the ones presented in this chapter could be used for these kinds of technologies.

Table 7. Examples of End-Use Efficiency Measures

Space Conditioning Thermal storage Duct sealing and balancing Improved efficiency Improved building design	**Refrigeration** Defrost control Multi-stage compressors Insulation / Weatherization High efficiency refrigeration cases
Water Heating Insulation blankets Heat pump water heaters Variable speed compressors Flow restricters High efficiency water heaters	**Lighting** High efficiency ballasts and reflector systems Lighting controls and occupancy sensors Daylight dimmers / switches Compact fluorescents Efficient fluorescent lamps High intensity discharge lamps
Building Envelope Insulating glass Low emissivity glass Insulation **Controls** Energy management systems	**Process Improvements** Drying / curing efficiency Economizers in recovery in steam systems Waste heat recovery Boiler and furnace maintenance Air compressor efficiency Repairing leaks and insulating tanks and pipes
	Operations and Maintenance
Motors Variable speed drives Improved motor rewinding High efficiency motors	**Ventilation** Improved efficiency Variable air volume Multi-speed or variable-speed motor

Renewable energy projects include solar thermal electricity generation and solar space conditioning, photovoltaics, wind, and hydroelectric. Renewable energy projects supply the amount of energy needed to provide a given level of service and are, therefore, similar to energy supply projects as well as energy-efficiency projects that reduce demand. If the renewable energy project displaces energy from carbon-based fuel combustion, GHG emissions are reduced. Biomass projects, which will require the MERV of energy displacement and carbon sequestration impacts, are discussed in the next chapter on forestry.

4.2. MERV Issues

Some of the key MERV issues affecting the energy sector are monitoring domain issues (see Sections 1.2.1 and 3.3.1). Energy efficiency and renewable energy projects can be implemented at the point of production, transformation, transmission, or end use. Thus, one of the monitoring domain issues to address is whether one will measure the GHG reductions and other impacts of energy-efficiency or renewable energy projects at the site of consumption, or further up the line toward the source of generation. What should the optimal system boundary be for the monitoring domain? Is there an easy rule of thumb to use for defining the optimal system boundary? Or must one monitor a country's entire national energy system for all energy-efficiency projects? We believe monitoring domain issues need to be identified during the project design stage, in order to avoid some monitoring domain issues (e.g., leakage) during the monitoring and evaluation stages. When leakage does occur, it may be mitigated or carbon estimates can be adjusted, such as a flat-rate adjustment to project-based abatement figures (Heister 1996).

When measuring the carbon reduction or sequestration impacts of energy-efficiency projects, it is possible that the actual reductions in carbon emissions are less than estimated because of changes in the behavior of project participants. For example, some occupants of buildings might raise their thermostat settings for winter heating due to lowered incremental energy costs resulting from improved insulation (commonly referred to as "snapback" or "takeback"). There is some debate in the literature regarding whether snapback is a significant factor for many efficiency measures.[1] There is also controversy on how any measured snapback effect should be included in a net benefit calculation. Some argue that it should be a debit to savings, while others argue that it represents enhanced service or increased amenity value and should at least net out any possible debit caused by increased usage. We believe it is important to raise the issue of snapback in this paper as it affects the calculation of GHG emissions, however, because of the uncertainties surrounding the topic, we believe it is premature at this time to include the issue in a MERV protocol.

Interventions targeting production or transmission efficiency require different monitoring and evaluation techniques than for distributed end-use interventions. For example, because production and transformation efficiency projects generally occur at one or a handful of facilities, sampling strategies for monitoring and evaluation are not required to determine GHG emissions impacts. Measurements must be taken at more than one site in order to monitor a single transmission efficiency project. Because end-

[1] A comprehensive review of 42 different snapback studies concluded that snapback can occur, but it is a localized phenomenon limited to specific end uses (Nadel 1993). For example, for residential space heating, 15 studies indicated that little if any takeback was likely, and for residential water heating there was no evidence of takeback. For residential lighting, increased operating hours increased energy use of compact fluorescent lamps by approximately 10% relative to what use would have been if operating hours remained unchanged (Nadel 1993). Clearly, one needs to examine the marginal use and demand for energy and non-energy services as part the calculation of snapback.

use efficiency projects typically target a large number of energy consumers, statistical evaluation methods are required.

The MERV of energy-efficiency projects is expected to be similar to that for renewable energy projects, although the former may be somewhat more difficult because energy-efficiency projects are typically smaller and more diffuse than larger, more centralized power supply options. Also, the output of renewable energy projects may be easier to measure (e.g., using a meter) compared to energy savings from energy-efficiency projects.

The evaluation of electric end-use efficiency and renewable energy projects requires an analysis of how the generation mix would have changed had the project not been implemented. Depending on the project, either baseload or peak load impacts (or both) will occur as a result of the project. If baseload or peak load energy is generated from fossil fuels, the reduction of energy consumption by end-users may reduce the generation required, and hence reduces the associated GHG emissions.

4.3. Data Collection and Analysis Methods

This section introduces some of the basic data collection and analysis methods used to produce energy-saving estimates (see DOE 1994b; Raab and Violette 1994). The methods vary in cost, accuracy, simplicity and technical expertise required. For example, the methods used for verification will be less technical than for evaluation, but they will require an understanding of the monitoring and evaluation processes, their results, and their applicability to the verification process. For energy-efficiency measures, verifying baseline and post-project conditions may involve inspections, spot measurement tests, or assessments (e.g., documentation of the assumptions and intent of the project design; functional performance testing and documentation evaluating the local acceptability of the energy efficiency measure(s); and adjusting the project to meet actual needs within the capability of the system) (Figueres et al. 1996).

Tradeoffs will need to be made for choosing the appropriate methods: e.g., level of accuracy and cost of data collection (see Section 4.3.7). These tradeoffs will also vary depending on the type of impacts that will be examined: energy impacts, GHG impacts, or non-GHG impacts. For example, it may be more difficult to collect data on GHG impacts than energy impacts, and non-GHG impacts than GHG impacts.

Data collection methods can include engineering calculations, surveys, modeling, end-use metering, on-site audits and inspections, and collection of utility bill data. Most monitoring and evaluation activities will focus on the collection of measured data; if no measured data is collected, then one will rely on engineering calculations and "stipulated" (or default) savings (as described in EPA's Conservation Verification Protocol — see Section 2.2.3). Data analysis methods can include engineering methods, basic statistical models, multivariate statistical models (including multiple regression models and conditional demand models), and integrative methods.

The methods used for data collection and the evaluation of non-electric end-use efficiency projects are similar to those used for electric end-use efficiency projects; there will, however, often be greater reliance on engineering methods and surveys because centralized billing information will generally not exist. Energy savings from other types of energy efficiency projects can also be calculated using the techniques in this chapter (e.g., utility bill monitoring can provide accurate savings estimates for solar thermal projects where the original fossil fuel was dedicated to the end-use requirement met by the solar system).[1] After reviewing these methods for evaluating energy savings, we discuss the calculation of GHG benefits resulting from these savings.

4.3.1. Engineering methods

Engineering methods are used to develop estimates of energy savings based on technical information from manufacturers on equipment in conjunction with assumed operating characteristics of the equipment. The two basic approaches to developing engineering estimates are engineering algorithms and engineering simulation methods (Violette et al. 1991).

Engineering algorithms are typically straightforward equations showing how energy (or peak) is expected to change due to the installation of an energy efficiency (or renewable energy) measure. They are generally quick and easy to apply. The accuracy of the engineering estimate, however, depends upon the accuracy of the inputs, and the quality of data that enters an engineering algorithm can vary dramatically.

Engineering building simulations are computer programs that model the performance of energy-using systems in residential and commercial buildings. These models use information on building occupancy patterns, building shell and building orientation (e.g., window area, building shape and shading) and information on all of the energy-using equipment. The input data requirements for the more complex

[1] Accounting for the shifting of energy use and related changes in emissions associated with fuel-switching activities creates a potentially more complex reporting situation: for example, comparing the indirect emissions reductions from reduced electricity use with the new direct emissions from increased onsite fossil fuel use.

simulation models are extensive and require detailed onsite data collection as well as building blueprints.

Building simulation models are best suited for space heating/cooling analyses and for predicting interactive effects of multiple measure packages where one of the measures influences space conditioning. Measures best addressed by simulation models include heating, ventilation, and air-conditioning (HVAC) measures, building shell measures, HVAC interactions with other measures, and daylighting measures. Equipment measures such as lighting, office equipment, and appliance use are typically calibrated outside the simulation, except for their interactive impacts.

Building simulation models are tools, and their usefulness is a function of the skill of the modeler, the accuracy of the input information, and the level of detail in the simulation algorithms. A key component of building energy simulation methods is the appropriate calibration of these models to actual consumption data. The calibration could involve monthly energy consumption data from bills (at a minimum), kW demand meters, run-time meters, and short-term end-use metering (e.g., two to six weeks of metering). One advantage of simulation models is that they take into account such factors as weather data and interactions between the HVAC system and other end uses. A primary disadvantage is that they are very time consuming and usually require specialized technical expertise, making them costly in the long run.

Engineering estimates are often developed as part of an ongoing project tracking database. Because of changes during project implementation, the engineering assumptions used at the design stage of a project need to be changed as evaluation data are collected (e.g., number of operating hours and specific measures installed). Engineering methods for use in assessing the impacts of energy-efficiency and renewable energy projects are improving as experience points out their strengths and weaknesses. Their value for impact evaluation also is increasing as actual field data is used to adjust or recalculate savings estimates. Engineering methods are often used as a complement to other evaluation methods rather than serving as stand-alone estimates of project impacts (see below).

Although engineering approaches are improving and increasing in sophistication, they cannot by themselves produce estimates of net project impacts (see Sections 3.3.2 and 4.4). The engineering estimates generally produce estimates of gross impacts and do not capture behavioral factors such as free riders and project spillover. It is possible to incorporate free rider and spillover factors from surveys and other evaluation sources in order to calculate net impacts. Engineering analyses may be most appropriate for: (1) the initial year of project implementation where monitoring will rely on engineering estimates; (2) projects where small savings are expected; (3) large industrial customers; and (4) new construction projects.

In sum, the advantages of engineering methods are that they are relatively quick and inexpensive to use and are probably most useful when integrated with other data collection and analysis methods. The primary disadvantage is that the data used in the calculations rely on assumptions that may vary in their level of accuracy. Accordingly, engineering analyses need to be “calibrated” with onsite data (e.g., operating hours and occupancy). Thus, as project information is collected, engineering estimates can be improved.

4.3.2. Basic statistical models for evaluation

Statistical models that compare energy consumption among projects before and after the installation of energy efficiency measures have been used as an evaluation method for many years (Violette et al. 1991). The most basic statistical models simply look at monthly billing data before and after measure installation using weather normalized consumption data. If the energy savings are expected to be a reasonably large fraction of the customer’s bill (e.g., 10% or more), then this change should be observable in the project’s bills. Smaller changes (e.g., 4%) might also be observed in billing data, but more sophisticated billing analysis procedures are often required. A weather normalized pre-/post-change in energy use is calculated for the projects. This can be viewed as a stand-alone estimate of impacts, or it can be compared to the change in energy use among a comparison group. Statistical models are most useful where many projects are being implemented (e.g., in the residential sector).

These simple statistical comparison estimates rely on the assumption that the comparison group is, in fact, a good proxy for what project participants would have done in the absence of the project. However, there are reasons to expect systematic differences between project participants and a comparison group (see Section 3.3.2). Consequently, evaluators may start with these basic statistical approaches because they are relatively inexpensive and easy to explain; these methods generally rely only on billing data and weather data for weather normalization. Evaluators should consider augmenting these methods with survey data and other measurements to test the underlying assumptions of these simple models. Additional modeling and verification methods may be needed before the results of these basic comparisons can be accepted as accurately representing the in-field impacts of an energy efficiency or renewable energy project (see Section 4.3.3).

The advantages of basic statistical models are that comparing the billing data is inexpensive, and the results are easy to understand and communicate. The disadvantages include limited applicability (because of the need for stable building operations or lack of prior billing records (e.g., new construction)), participant samples of significant size are required for validity, and peak impacts cannot be evaluated.

4.3.3. Multivariate statistical models for evaluation

In project evaluation, more detailed statistical models may need to be developed to better isolate the impacts of an energy-efficiency or renewable energy project from other factors that also influence energy use. Typically, these more detailed approaches use multivariate regression analysis as a basic tool (Violette et al. 1991). Regression methods are simply another way of comparing kWh or kW usage across sets of projects and comparison groups, holding other factors constant. Regression methods can help correct for problems in data collection and sampling. If the sampling procedure over- or under-represents specific types of projects (e.g., large-scale energy intensive projects) among either project participants or the comparison group, the regression equations can capture these differences through explanatory variables. Two commonly applied regression methods are conditional demand analysis and statistically adjusted engineering models (Violette et al. 1991).

4.3.4. End-use metering

Energy savings can be measured for specific equipment for specific end uses through end-use metering (Violette et al. 1991). This type of metering is required before and after a retrofit to characterize the performance of the equipment under a variety of load conditions. The advantage of end-use metering is that it provides a greater degree of accuracy than engineering estimates or short-term monitoring for measuring energy use (see below). In addition, the meter can calculate the energy change on an individual piece of equipment in isolation from the other end-use loads (as opposed to billing analysis which captures the effect at the building or meter level). The disadvantages of end-use metering are: (1) it requires specialized equipment and expertise, typically more costly than the other methods, and therefore most samples need to be small; (2) the small samples may lead to biases in sample selection and problems in representativeness; (3) end-use metering of post-participation energy consumption alone does not, in and of itself, improve estimates of project impacts; and (4) end-use metering experiments to measure both pre-and post-installation consumption are difficult to construct, especially in identifying project participants before their becoming participants to allow the pre-measure end-use metering. Accordingly, end-use metering is more often seen as a data collection method (rather than a data analysis method) that can provide useful information for integrative methods (see Section 4.3.6).

4.3.5. Short-term monitoring

Short-term monitoring refers to data collection conducted to measure specific physical or energy consumption characteristics either instantaneously or over a short time period. This type of monitoring is conducted to support evaluation activities such as engineering studies, building simulation and statistical analyses (Violette et al. 1991). Examples of the type of monitoring that can take place are spot watt measurements of efficiency measures, run-time measurements of lights or motors, temperature measurements, or demand monitoring. Short-term monitoring is gaining increasing attention as evaluators realize that for certain energy-efficiency measures with relatively stable and predictable operating characteristics (i.e., commercial lighting, some motor applications, wind turbines), short-term measurements will produce gains in accuracy nearly equivalent to that of longer-term metering at a fraction of the cost.

Short-term monitoring is a useful tool for estimating energy savings when the efficiency of the equipment is enhanced, but the operating hours remain fixed. Spot metering of the connected load before and after the activity quantifies this change in efficiency with a high degree of accuracy. For activities where the hours of operation are variable, the actual operating (run-time) hours of the activity should be measured before and after the installation using a run-time meter. Thus, the advantage of the spot meter is that it is simple and easy to apply. This method is more accurate than using engineering calculations, since the parameters are measured instead of being assumed. The primary disadvantage is its limited applicability (i.e., where operating hours are the same before and after treatment). Similar to end-use metering, short-term monitoring is more often seen as a data collection method (rather than a data analysis method) that can provide useful information for integrative methods (see Section 4.3.6).

4.3.6. Integrative methods

Integrative methods combine one or more of the above methods to create an even stronger analytical tool. These approaches are rapidly becoming the state of the practice in the evaluation field (Raab and Violette 1994). The most common integrative approach is to combine engineering and statistical models where the outputs of engineering models are used as inputs to statistical models. These methods are often called Statistically Adjusted Engineering (SAE) methods or Engineering Calibration Approaches (ECA). Although they can provide more accurate results, integrative methods typically increase the complexity and expense. To reduce these costs while maintaining a high level of accuracy, a related set of procedures has been developed to leverage high cost data with less expensive data. These leveraging approaches typically utilize a statistical estimation approach termed ratio estimation that allows data sets on different sample sizes to be leveraged to produce estimates of impacts (see Violette and Hanser 1991).

4.4. Net Energy Impacts and Comparison Groups

As noted in Sections 3.3.2, comparison groups are needed for evaluating the net impacts of energy efficiency and renewable energy projects. This approach can capture time trends in consumption that are unrelated to project participation. For example, if the comparison groups' utility bills show an average reduction in energy use of 5% between the pre- and post-periods, and the participants' bills show a reduction of 15%, then it may be reasonable to assume that the estimated project impacts will be 15% minus the 5% general trend for an estimated 10% reduction in use being attributed to the project. Similarly, if the project has affected 80% of the comparison group, then all or a portion of the energy savings from the comparison group may be added to the direct impacts to the project (as part of the market transformation aspects of the project). None of the existing guidelines and protocols, however, specifically recommend including the additional savings due to the impacts of the project outside of the project area. This is a monitoring domain issue that the guidelines or policy rules need to address (see Sections 1.2.1 and 3.3.1).

4.5. Calculating GHG Impacts

Net emission reductions can be calculated in three ways: (1) if GHG emissions are monitored, then the difference in measured emissions between the reference and project case is calculated; (2) if emissions reductions are based on fuel-use or electricity-use data, then default emissions factors can be used, based on utility or nonutility estimates (e.g., see Appendix B in DOE 1994b); or (3) emissions factors can be based on generation data specific to the situation of the project (e.g., linking a particular project on an hourly or daily basis to the marginal unit it is affecting). In the last two methods, emissions factors translate consumption of energy into GHG emission levels (e.g., tons of a particular GHG per kWh saved). In contrast to the default emission factors (method #2), the advantage of using the calculated factors (method #3) is that they can be specifically tailored to match the energy efficiency characteristics of the activities being implemented by time of day or season of the year. For example, if an energy-efficiency project affects energy demand at night, then baseload plants and emissions will probably be affected. If a solar photovoltaic project, however, generates electricity during the middle of the day, then peak capacity plants and emissions may be affected. Since different fuels are typically used for baseload and peak capacity plants, then emission impacts will also differ.

The calculations become more complex if one decides to use the emission rate of the marginal generating plant (multiplied by the energy saved) for each hour of the year, rather than the average emission rate for the entire system (i.e., total emissions divided by total sales) (Swisher 1997). For the more detailed analysis, one must analyze the utility's existing expansion plan to determine the generating resources that would be replaced by saved electricity or displaced by renewables, and the emissions from these electricity-supply resources. Moreover, one would have to determine if the planned energy-efficiency measures or renewables would reduce peak demand sufficiently and with enough reliability to defer or obviate planned capacity expansion. If so, the deferred or replaced source would be the marginal expansion resource to be used as a baseline. This type of analysis may result in more accurate estimates of GHG reductions, but this method will be more costly and require expertise in utility system modeling.

4.6. Summary

Several methods are available for collecting data on energy-efficiency and renewable energy projects: e.g., engineering calculations, surveys, modeling, end-use metering, on-site audits and inspections, and collection of utility bill data. Similarly, several methods are available for evaluating these kinds of projects: e.g., engineering methods, basic statistical models, multivariate statistical models (including multiple regression models and conditional demand models), and integrative methods.

There is no one approach that is "best" in all circumstances (either for all project types, evaluation issues, or all stages of a particular project). The costs of alternative approaches will vary and the selection of evaluation methods should take into account project characteristics. The appropriate approach depends on the type of information sought, the value of information, the cost of the approach, and the stage and circumstances of project implementation. The applications of these methods are not mutually exclusive; each approach has different advantages and disadvantages (Table 8). Using more than one method can be informative. Employing multiple approaches, perhaps even conducting different analyses in parallel, and integrating the results, will lead to a robust evaluation. Such an approach builds upon the strengths and overcomes the weaknesses of individual approaches. Also, each approach may be best used at different stages of the project life cycle and for different measures or projects. An evaluation plan should specify the use of various analytical methods throughout the life of the project and take into account the financial constraints, staffing needs, and availability of data sources.

Within the application of impact evaluation methods, several trends are being observed in the field of project evaluation which may affect the type of MERV guidelines that may be developed: (1) a resurgence in the use of engineering methods for energy-efficiency project evaluation, as engineering models have improved and have integrated the results of field studies; (2) declining costs of infield metering and monitoring technologies; (3) better measurement and data collection protocols; and (4) an increased emphasis on collecting data during project implementation to better support project evaluation (Raab and Violette 1994).

Table 8. Advantages and Disadvantages of Data Collection and Analysis Methods

Methods	Advantages	Disadvantages
Engineering Methods	Relatively quick and inexpensive. Most useful as a complement to other methods. Methods are improving.	Need to be calibrated with onsite data. Not good for net impact evaluation.
Basic Statistical Models	Relatively inexpensive and easy to explain.	Assumptions need to be confirmed with survey data and other measured data. Limited applicability. Cannot evaluate peak impacts. Large sample sizes needed.
Multivariate Statistical Methods	Can better isolate project impacts than basic statistical models.	Same disadvantages as for basic statistical models. Relatively more complex, expensive, and harder to explain than basic statistical models.
End-use Metering	Most accurate method for measuring energy use. Most useful for data collection, not analysis.	Can be very costly. Small samples only. Requires specialized equipment and expertise. Possible sample biases. Difficult to generalize to other projects. Does not, by itself, calculate energy savings. Difficult to obtain pre-installation consumption.
Short-term Monitoring	Useful for measures with relatively stable and predictable operating characteristics. Relatively accurate method. Most useful for data collection, not analysis.	Limited applicability. Does not, by itself, calculate energy savings.
Integrative Methods	Relatively accurate.	Relatively more complex, expensive, and harder to explain than some of the other models.